PATENT COOPERATION TREATY

# PCT

## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

| Applicant's or agent's file reference | **FOR FURTHER ACTION** | see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 b low. |
|---|---|---|
| H-599-7452 | | |
| International application No. | International filing date *(day/month/year)* | (Earliest) Priority Date *(day/month/year)* |
| PCT/IB 00/ 00794 | 13/06/2000 | 11/06/1999 |
| Applicant | | |
| HOLTRONIC TECHNOLOGIES PLC | | |

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

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   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has be n furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [ ] the text is approved as submitted by the applicant.

   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the dat of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** t b publish d with the abstract is Figure No. 3

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the inv ntion.

   [ ] None of the figures.

**Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)**

The abstract is changed as follows :

line 2 : after "mask" insert "(45)" ;
line 3 : after "photoresist" insert "(15)" ;
line 4 : after "object" insert "(17)" ;
line 5 : after "beams" insert "(19)".

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 00/00794

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 G03H1/00 G03F7/20

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G03H G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
WPI Data, PAJ, EPO-Internal, INSPEC

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 5 640 257 A (CLUBE FRANCIS S M)<br>17 June 1997 (1997-06-17)<br>cited in the application<br>column 5, line 6 -column 6, line 57<br>figure 2<br>--- | 1,17,22,<br>25,33,37 |
| A | US 3 796 476 A (FROSCH A ET AL)<br>12 March 1974 (1974-03-12)<br>cited in the application<br>column 3, line 38 -column 4, line 51<br>figures 5,6<br>---<br>-/-- | 1,22,25,<br>37 |

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 27 September 2000 | 05/10/2000 |

| Name and mailing address of the ISA | Authorized officer |
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| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Krametz, E |

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Form PCT/ISA/210 (second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 00/00794

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication,where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | GB 2 176 628 A (ROSS IAN NORMAN;DAVIS GILLIAN MARGARET)<br>31 December 1986 (1986-12-31)<br>page 1, line 6 - line 10<br>page 1, line 73 - line 86<br>page 2, line 47 - line 51<br>page 3, line 20 - line 35 | 1,8,21, 22,25, 26,37 |
| A | US 5 648 857 A (ANDO HIROSHI ET AL)<br>15 July 1997 (1997-07-15)<br>column 2, line 30 -column 4, line 10 | 1,22,25, 37 |

1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB 00/00794

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 5640257 A | 17-06-1997 | GB 2271648 A | 20-04-1994 |
| | | DE 69327439 D | 03-02-2000 |
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**Published:**
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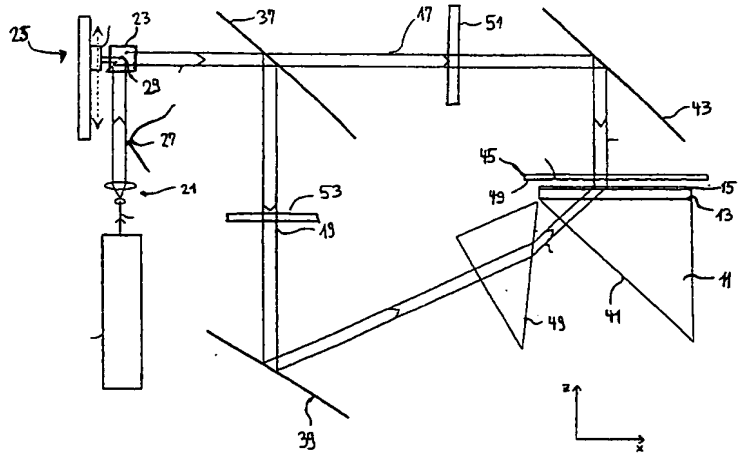
*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: METHOD AND APPARATUS FOR RECORDING A HOLOGRAM FROM A MASK PATTERN BY THE USE OF TOTAL INTERNAL REFLECTION HOLOGRAPHY AND HOLOGRAM MANUFACTURED BY THE METHOD




(57) Abstract: The present invention relates to a method and an apparatus for forming a hologram from a mask (45). According to the invention a photoresist (15) is used as the holographic recording medium and the planes of polarisation of the object (17) and reference beams (19) incident on the holographic recording medium are arranged such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are also substantially orthogonal. Preferably, just the transmission hologram is formed in the holographic recording layer.

WO 01/13181 A1

# Method and apparatus for recording a hologram from a mask pattern by the use of total internal reflection holography and hologram manufactured by the method

The present invention relates to a total internal reflection holographic apparatus and a method of forming a hologram and reconstructing an image therefrom.

The principles of total internal reflection (TIR) holography have been described already in US 4,857,425. Since then many efforts have been made to make use of TIR holography in the microelectronics industries. Prior art references are e.g. US 4,917,497, US 4,966,428, 5,187,372, US 5,640,257 and European application no. 98300188 whose contents are herewith incorporated by reference.

Frosch et al. (US 3,796,476)recorded TIR holograms of mask patterns using photographic emulsion, i.e. grains of silver halide dispersed in a gelatin film, as the holographic recording material. Such a material records information by modulating the bulk properties of the material (either its absorption or refractive index) and is referred to hereinafter as a "volume recording material".

Normally in TIR holography the three recording beams (object beam, incident reference beam and totally internally reflected beam) give rise to three holograms in the recording material. The interference between the incident reference beam and the object beams, produces a reflection hologram, the interference between the totally internally reflected reference beam and the object beam produces a transmission hologram and the interference between the incident reference

beam and the totally internally reflected reference beam produces a Lippmann hologram. Frosch et al. disclosed object and reference beams whose planes of polarisation they claimed to be orientated such that only one hologram is formed (either the reflection hologram formed by interference of the object beam with the incident reference beam or the transmission hologram formed by the interference of the object beam with the reflected reference beam) for the purpose of avoiding the (perceived) problem of loss of resolution due to shrinkage of the emulsion between recording and replay. According to Frosch et al., when both of the aforementioned holograms are present, shrinkage of the emulsion causes the images generated by the two holograms of Frosch et al. to shift relative to each other, and this degrades the resolution.

Since 1974, when US 3,796,476 was published, no subsequent prior art on TIR holography directed at high resolution lithography has employed the polarisation scheme proposed by Frosch et al. The reasons for this are as explained above: for volume holography, not only does the method not offer any useful purpose but also the scheme disclosed does not work as described.

The overwhelming part of the literature relating to the application of TIR holography to microlithography concerns volume holography. In particular, the holograms are generally recorded in photopolymer materials manufactured e.g. by DuPont Nemours. With this material the pattern in the mask is recorded as a modulation of the refractive index in a layer of typically ~10 μm thickness. This material functions well for recording holograms using visible or near ultra-violet

light (i.e. down to a wavelength of ~350 nm). In contrast thereto, "surface-relief" holography records the mask pattern information as a modulation of thickness of the recording layer.

In 1988 Ross et al. reported on recording TIR holograms of mask patterns using a wavelength of 458 nm, S-polarisation (i.e. electric field vector perpendicular to the plane of incidence of the reference beam at the recording layer) for the object and reference beams and using the surface-relief material photoresist as the holographic recording material. They used an argon-ion laser operating at 458 nm as the light source. They were able to obtain hologram efficiencies of only ~ 5 % which they partly attributed to the problem of obtaining deep surface-relief structures in the photoresist because of the intensity distribution of the 3 interfering beams in the photoresist (object beam, incident reference beam and reflected reference beam) and the development process which preferentially etches the high intensity regions.

An approach for achieving higher resolution from TIR holographic lithography is to reduce the wavelength of the light source for recording and replay from the commonly used value of 364 nm to a value of, for instance, 248 nm or 193 nm which are in the deep ultra-violet part of the spectrum and are produced by krypton fluoride and argon fluoride excimer lasers respectively. These laser sources are widely used by the micro-electronics industry in lens-based lithographic systems. Volume holographic recording materials for such wavelengths are however not readily available.

It is an object of the present invention to provide an improved method and apparatus for forming a total internal reflection (TIR) hologram and reconstructing an image therefrom. In particular, it is an object to provide better resolution so that still smaller features can be recorded in a hologram and subsequently be reproduced therefrom.

According to the invention there is provided a method according to the pre-characterizing part of claim 1 wherein a photoresist is employed as the holographic recording medium and the planes of polarisation of the object and reference beams incident on the holographic recording medium are arranged such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are also substantially orthogonal.

However, the present inventors have found that the contention of Frosch et al., namely that shrinkage causes a relative shift of the two images reconstructed from the two holograms, is not true. In fact, shrinkage of the emulsion does not cause either of the images to shift and thus there is no relative shift of the two.

The present inventors have further found that the teaching of Frosch et al. with respect to the planes of polarisation required of the object and reference beams to limit the number of holograms formed to just one is also, in fact, invalid. Frosch et al. assert that the plane of polarisation of the incident reference beam should be at an angle of 45° with respect to its plane of incidence and that the plane of

polarisation of the object beam should be parallel or orthogonal to the plane of polarisation of the incident reference beam. They state (US 3,796,476, col. 4 lines 35-42) that "this selection of the plane of polarisation of the (incident) reference beam $B_1$ ensures that near the bordering angle of the total reflection - owing to the turning of the plane of polarisation by 90° - no interference pattern can form between the two reference beams $B_1$ and $B_2$". The authors of the present invention have found this statement to be incorrect in that the plane of polarisation selected for the reference beam is not rotated by 90° on total internal reflection but instead remains substantially unchanged and results in a strong interference pattern being formed between the two reference beams $B_1$ and $B_2$.

Advantageously, substantially only the transmission hologram is recorded in the holographic recording layer. Surprisingly, this gives the best results as to resolution and contrast of the hologram. These findings are in contrast to the teaching of Frosch et al. (US 3,796,496) who teach to record the reflection hologram. By recording substantially only the transmission hologram, TIR holography can be used effectively for recording submicron features in surface relief holograms. Advantageously, the plane of polarisation of the object beam is at 45° to the plane of incidence of the reference beam at the holographic recording layer. This allows to further reduce the contribution to the reflection and Lippman holograms.

Advantageously, the photoresist material is selected such that its thickness (d) and absorption (a) meet the condition $a * d < 1$. Since the resist thickness (d) is coupled with the

absorption coefficient (a) to determine the transmittance (T) of the resist through the formula $T = \exp(-4\pi\kappa/\lambda_o)^* = \exp(-a^*d)$, the product a*d is of concern ($\kappa$=extinction coefficient, $\lambda$ = wavelength). The photoresist should preferably also be selected such that its contrast described by its gamma-value satisfies the condition $\gamma < 3$. Advantageously, the resolution of the photoresist is selected such that its resolution described by the smallest period, $\Lambda$, of grating that can be optically recorded in the material with a modulation depth $(d_{max} - d_{min})/(d_{max} + d_{min}) > 25$ % should satisfy the condition $\Lambda < 200$ nm. It has further been found that the best results can be obtained if the thickness of the photoresist layer is less than 500 nm, preferably between 100 and 300 nm and most preferably between 200 and 300 nm.

It has additionally been found that both positive and negative photoresists can be employed.

It is preferred that the laser light used has a wavelength of below 300nm, and preferably a wavelength of 248 nm or 193 nm. Further, it is advantageous that the intensity of the reference beam exceeds that of the object beam, by a factor 2, and preferably is 4 : 1.

For a better long-term stability of the hologram it is further advisable that the image recorded in the photoresist as a surface relief hologram be subsequently transferred into the underlying substrate material by an etching process, such as by plasma etching.

Although the hologram can be formed in a single exposure, preferably beams of a restricted cross-section are used and the hologram is formed by a scanning operation. The inventive process is particularly useful for transferring features of less than 1 μm, preferably less than 0.5 μm, from a mask into a hologram for use in microlithography.

Preferably, the angle of incidence of the beam in the recording layer is less than 45°, preferably less than 42° and most preferably less than 40°. By this arrangement the contribution to the reflection and Lippman holograms can be reduced to a minimum. Advantageously, a photoresist is employed whose refractive index at the exposure wavelength is greater than 1.6 and preferably greater than 1.7.

The present invention relates also to a total internal reflection holographic recording apparatus for recording a hologram from a mask, comprising

- an optical coupling element for receiving a substrate on a first face;
- a substrate bearing a holographic recording layer, the substrate being in optical contact with said first face of the optical coupling element,
- a mask bearing a pattern arranged in proximity and parallel to the holographic recording layer,
- a light source for generating a light beam;
- optical means for generating a collimated light beam of a selected cross-section;
- means, such as a beam-splitter, prism or the like, for dividing the collimated light beam into two coherent light beams, a reference light beam and an object light beam;
- means for directing the reference light beam at a second

face of the coupling element such that it illuminates the interface between the holographic recording layer and the ambient medium at an angle greater than the critical angle;

- means for directing the object light beam at the first face of the coupling element such that it is overlaps the reference beam in the plane of the holographic recording medium on the substrate in contact with the first face;

**characterized in that**

- the holographic recording medium is a photoresist and
- means are provided for arranging the planes of polarisation of the object and reference beams incident on the holographic recording medium such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are also substantially orthogonal. Further advantageous features are defined in the sub-claims.

The coupling element is for instance a prism or a grating on a transparent plate such as a fused silica substrate as described in the co-pending European application no. EP 98300188 (published under no. EP 0 930 549). The coupling element disclosed in EP 0 930 549 is a substrate having a periodic grating structure on the first surface whose period, in relation to the incident angle and wavelength of the light and the refractive index of the plate material is such that only a zeroth and one first order beams of the light being incident on the first surface at a predetermined incident angle are transmitted into the plate and that the transmitted first diffraction order is essentially totally reflected at the second surface/air interface. Thus, the grating can behave like a prism in a TIR holographic process.

Advantageously the apparatus comprises means for measuring the gap between the holographic recording layer and the mask preferably at the center of the scanning illumination beam, and means for adjusting the separation between the holographic recording layer and the mask.

According to another independent aspect of the invention a method of forming a hologram from a information containing mask is provided, comprising the following steps:

- arranging a substrate bearing a layer of a holographic recording medium on a first face of a coupling element and in optical contact therewith;
- arranging a information containing mask in a spaced relationship and parallel to the substrate;
- generating an illumination light beam and then splitting the light beam into an object beam and a reference beam;
- directing the object beam through the mask to the substrate such that it overlaps with the reference beam in the holographic recording medium;

**further including the steps of**

- employing a photoresist as the holographic recording medium;
- directing the reference beam to a second face of the coupling element in a way that the condition for total internal reflection at the interface between the recording medium and the ambient medium is fulfilled and so that the angle of incidence of the beam in the recording layer is less than 45°, preferably less than 42° and most preferably less than 40°;
- arranging the planes of polarisation of the object and reference beams incident on the holographic recording medium

such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are also substantially orthogonal.

The authors of the present invention have determined that with an angle of incidence for the reference beam within the holographic recording layer of 45°, which is the angle employed by Frosch et al. and also the angle generally employed in the field of TIR holography using volume recording materials, that no planes of polarisation of the incident reference and object beams exist that permit only or substantially only one hologram to be formed in the holographic recording layer.

The inventors have found that photoresist materials generally have higher refractive indices than the volume recording materials employed in the prior art (whose index is generally ~1.5)and this allows the angle of incidence of the reference beam in the recording layer to be significantly less than 45° without violating the condition for total internal reflection Arranging that the angle of incidence of the reference beam is significantly less than an angle of 45° permits the planes of polaristion of the reference and object beams to be selected in order to suppress the Lippmann and reflection holograms so that substantially only the transmission hologram is formed.

The contrast of the Lippmann hologram $C_{Lipp}$ is dependent on the polarisation vectors of the incident and reflected reference beams according to

$$C_{Lipp} = (\mathbf{P}_{ir} \cdot \mathbf{P}_{rr})$$

where $\mathbf{P}_{ir}$ and $\mathbf{P}_{rr}$ are the polarisation vectors of the incident and reflected reference beams. If we neglect polarisation rotation on total internal reflection (which is a valid approximation near the critical angle) then $C_{Lipp}$ is minimized when

$$\tan^2 \theta_r = \cos 2\,\theta_{pr} \qquad \text{equ. (1)}$$

where $\theta_r$ is the angle the plane of polarisation of the reference beam makes with the plane of incidence of the reference beam at the holographic recording layer and where $\theta_{pr}$ is the angle of incidence of the reference beam in the photoresist.

Similarly, the contrast of the reflection hologram is dependent on

$$C_{refl} = (\mathbf{P}_{ir} \cdot \mathbf{P}_{o})$$

where $\mathbf{P}_0$ is the polarisation vector of the incident object beam and this is minimized when

$$\tan \theta_r \tan \theta_0 = -\cos \theta_{pr} \qquad \text{equ. (2)}$$

Thus, equations (1) and (2) allow the planes of polarisation of the incident reference and object beams to be selected in order to that the transmission hologram is preferentially recorded in the holographic layer.

Let us take as an example a layer of photoresist of refractive index 1.8 on a transparent substrate of refractive index 1.5 and with the angle of incidence of the reference

beam in the substrate to be 45°. From Snell's law the angle of incidence of the reference beam in the photoresist, $\theta_{pr}$, is calculated to be :

$$\theta_{pr} = 36°$$

Hence, using equ. (1) above, the plane of polarisation of the incident reference beam should be oriented such that

$$\theta_r = 29°$$

and, using equ. (2), the plane of polarisation of the object beam should be oriented such that

$$\theta_o = -56°$$

Whereas the formulae and angles calculated above are applicable for masks containing line geometries oriented parallel to a single axis, in the case of masks containing grating structures in two orthogonal x and y directions, the inventors have found that advantageously the plane of polarisation of the object beam should be in the range -43° to -47° and preferably -45° and that the plane of polarisation of the reference beam should again be calculated according to equ. 2 above. Thus, for the particular photoresist considered in the example above, the corresponding angle of polarisation of the reference beam should be in the range 37° to 41° and preferably 39°.

Advantageously, a photoresist is employed whose refractive index at the exposure wavelength is greater than 1.6 and preferably greater than 1.7. Further advantageous embodiments of the invention are defined in the subclaims.

Subject of the present invention is also a total internal reflection holographic recording apparatus for recording a hologram from a mask, comprising

- an optical coupling element for receiving a substrate on a first face;
- a substrate bearing a holographic recording layer, the substrate being in optical contact with said first face of the optical coupling element,
- a mask bearing a pattern arranged in proximity and parallel to the holographic recording layer,
- a light source for generating a light beam;
- optical means for generating a collimated light beam of a selected cross-section;
- means, such as a beam-splitter, prism or the like, for dividing the collimated light beam into two coherent light beams, a reference light beam and an object light beam;
- means for directing the reference light beam at a second face of the coupling element such that it illuminates the interface between the holographic recording layer and the ambient medium at an angle greater than the critical angle;
- means for directing the object light beam at the first face of the coupling element such that it is overlaps the reference beam in the plane of the holographic recording medium on the substrate in contact with the first face,

**whereby** the holographic recording medium is a photoresist and the directing means for the reference light beam further arranges that the angle of incidence of the reference beam in the holographic recording layer is less than 45°, preferably less than 42°and most preferably less than 40° and means are provided for arranging the planes of polarisation of the object and reference beams incident on the holographic recording medium such that their polarisation vectors are

substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are also substantially orthogonal. Further advantageous embodiments of the invention are defined in the dependent claims.

Advantageously a photoresist is selected whose refractive index is higher than a value of 1.6 and preferably higher than 1.7 at the wavelength of the light source.

For a more complete understanding of the present invention, reference is now made to the figures, like numerals being used for like and corresponding parts of the various drawings.

Fig.1 is a schematic view of a total internal reflection (TIR) holographic recording apparatus comprising a scanning stage for scanning an illumination beam in x and y direction (only x dimension shown);

Fig. 2 a view of the scanning stage from above;

Fig.3 the inventive TIR holographic recording system

Figure 1 shows a known TIR holographic system for forming an a hologram from a mask pattern. It comprises a prism 11 which a substrate 13 bearing a holographic recording layer 15 is index-matched by means of an appropriate matching fluid. The matching fluid is applied between prism 11 and substrate 13 and exhibits the same refractive index as the prism 11 and substrate material so that a light beam which passes from the

prism 11 into the substrate 13 preferably is not reflected at the prism/substrate interface.

For forming a hologram two light beams are necessary, an object beam 17 and a reference beam 19. The object and reference beams 17,19 are coherent laser beams which are derived from the same laser source. The normally narrow laser light beam is first preferably expanded and collimated by an expansion and collimating optics 21 to a beam of a diameter of about 15 to 20 mm by a known optical expansion means. Thereafter the expanded and collimated beam is directed by a mirror 23 towards a xy scanning stage 25. The two-axes xy scanning stage serves to deflect the collimated light beam 27 such that the beam can traverse in a raster pattern essentially the entire prism face onto which the substrate 13 bearing the recording medium 15 is arranged. For this purpose the scanning stage 25 (see figure 2) comprises a first mirror 29 on a first carriage 31 movable in the x direction which deflects the light beam to a second mirror 33 on a second stage 35 moveable in the x direction that is also mounted to the first carriage. This second mirror 35 deflects the beam onto further large mirrors 37,39 such that the light beam enters the prism 11 through the hypotenuse face 41 and arrives at the substrate bearing face of the prism at an angle which is greater than the critical angle. For, the orientation of the stage system it is preferable that the beam be scanned in the x direction and stepped in the y direction (it also allows the beam to be scanned in the y direction and stepped in the x direction, though this is not desirable because of mechanical wear to the first stage).

The mirror 37 is semi-transparent and functions as beam splitter for generating the object beam 17. The object beam 17 is directed to mirror 43 which deflects the beam 17 towards the substrate 13 at normal incidence.

For forming the hologram a mask 45 containing a mask pattern 47 is placed parallel and in a spaced relationship to the substrate 13. The object beam 17 penetrates the mask 45 and the transmitted light of the object beam interferes with the reference beam 19.

For forming a large-size hologram the reference and object light beams are preferably scanned in an aligned relationship across the entire mask 45 and substrate 13 surfaces in a raster scan-and-step operation whereby the object and the reference beams 17,19 interfere with each other in the holographic recording medium 15 thereby forming the desired hologram.

In order that the object and reference beams 17, 19 remain superposed as they scan across the mask and recording layer, an additional prism 49 is provided in the light path of the reference beam which compresses the reference beam in one direction.

The reconstruction of an image from the hologram requires that the direction of the reference light beam is reversed, i.e. being in the opposite direction to that of the reference beam in the hologram formation process. The interaction of the reversed light beam or reconstruction beam, with the hologram produces a positive image of the circuit pattern in the photosensitive layer or, for instance, a silicon wafer

placed at the same distance from the hologram as was the mask from the recording layer during the hologram formation process.

In order that the image generated from the hologram can be later printed in focus it is preferable that during the exposure the local gap between mask and recording layer where the beams are illuminating them is continuously measured and adjusted to a constant value. The apparatus and methodology for this are not described here since they are adequately described already in the prior-art.

Figure 3 shows an embodiment according to the present invention. The laser source in this case is a frequency-doubled argon ion laser emitting a beam at a wavelength of 248 nm. The transmissive components in the optical system including the beamsplitter, prisms, hologram substrate and lens are manufacture from fused silica which is transparent at the wavelength of 248 nm.

According to the invention a photoresist is selected as the holographic recording medium 15, in particular a 250 nm thick layer of the SNR 240 manufactured by Shipley. This resist has a refractive index of 1.8 at the exposure wavelength. The mirror 39 directs the reference beam into the prism 11 such that the angle of incidence of the beam in the photoresist layer is 36°.. The planes of polarisation of the object and reference beams incident on the holographic recording medium are arranged such that their polarisation vectors are according ot the values calculated in the example quoted earlier in the summary of the invention so that they are substantially mutually orthogonal in the holographic

recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are also substantially orthogonal in order that the transmission hologram is preferentially recorded in the holographic recording layer. The latter is achieved by providing polarisation ratating plates 51,53 arranged in the light paths of the object and reference beams 17,19. Alternatively such polarisation rotating means for the object and reference beams might be integrated into the beamsplitter component.

A filter plate 55 is additionally included in the object beam path such that the object -t- reference beam intensity ratio is 1:4.

The exposure parameters, namely the laser power, scanning speed and step size are selected in order that the depth of the surface-relief profile formed in the developed resist is preferably greater that 50 nm and optimally about 100 nm.

To minimise scattering in the developed structure it is advisable that a slow and gentle development process be used in particular the developer MF322 manufactured by Shipley diluted 1:1 with water and that the solution be cooled to a temperature of ~9°C. The development time of a 5 s can be employed. It is further recommended that the resist be prebaked at a temperature of 130°C prior th exposure to drive off solvents that can also result in increased scattering in the final structure. It is also recommended that its resist is coated using an enclosed chuck.

It is to be noted that for the purpose of the present invention scanning of the reference and object beams is not an essential feature and that, accordingly, also stationary expanded beams can be used as disclosed in US 4,966,428 to Phillips.

The present invention relates to a method and an apparatus or system for forming a hologram from a mask. According to the invention a photoresist is used as the holographic recording medium and the planes of polarisation of the object and reference beams incident on the holographic recording medium are arranged such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are also substantially orthogonal. Preferably the object and the incident reference beams as well as their polarisations are selected or adjusted that essentially just the transmission hologram is recorded in the holographic recording layer and that at least the reflection hologram is essentially suppressed.

Claims:

1. Method of forming a hologram from a information containing mask, comprising the following steps:
- arranging a substrate bearing a layer of a holographic recording medium on a first face of a coupling element and in optical contact therewith;
- arranging a information containing mask in a spaced relationship and parallel to the substrate;
- generating an illumination light beam and then splitting the light beam into an object beam and a reference beam;
- - directing the reference beam to a second face of the coupling element in a way that the condition for total internal reflection at the interface between the recording medium and the ambient medium is fulfilled
- directing the object beam through the mask to the substrate such that it overlaps with the reference beam in the holographic recording medium;
**further including the steps of**
- employing a photoresist as the holographic recording medium; and
- arranging the planes of polarisation of the object and reference beams incident on the holographic recording medium such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are also substantially orthogonal.

2. Method according to claim 1, characterized in that substantially only the transmission hologram is recorded in the holographic recording layer.

3. Method according to claim 1 or 2, characterized in that a photoresist is employed whose refractive index at the exposure wavelength is greater than 1.6 and preferably greater than 1.7.

4. Method according to claim 1 or 3, characterized in that the plane of polarisation of the object beam is at 45° to the plane of incidence of the reference beam at the holographic recording layer.

5. Method according to any of claims 1 to 4, characterized in that the photoresist material is selected such that its thickness (d) and absorption (a) meet the condition $a * d < 1$.

6. Method according to any of claims 1 to 5, characterized in that the photoresist is selected such that its contrast described by its gamma-value satisfies the condition $\gamma < 3$.

7. Method according to any of claims 1 to 6, characterized in the photoresist is selected such that its resolution described by the smallest period of grating that can be optically recorded in the material is with a modulation depth $(d_{max} - d_{min})/ (d_{max} - d_{min}) > 25\%$ satisfies the condition $\Lambda < 200$ nm.

8. Method according to any of claims 1 to 7, characterized in that laser light of a wavelength below 300nm, and preferably of a wavelength between 150 and 260 nm for recording the hologram is used.

9. Method according to any of claims 1 to 8, characterized in the polarisation angles are selected according to the refractive index of the photoresist.

10. Method according to any of claims 1 to 9, characterized in that a combination of polarisation angles of between 37 to 44°, preferably 39° for the reference beam and - -43 to -47°, preferably -45° for the object beam with respect to the plane of incidence are applied.

11. Method according to any of claims 1 to 10, characterized in that the intensity of the reference beam exceeds that of the object beam.

12. Method according to any of claims 1 to 11, characterized in that the intensity of the reference beam exceeds that of the object beam by a factor 2, and preferably is 4 : 1.

13. Method according to any of claims 1 to 12, characterized in that the intensity ratio of the object and reference beams is between 3:1 and 5:1, and preferably about 4:1.

14. Method according to any of claims 1 to 13, characterized in that the thickness of the photoresist layer is less than 500 nm, preferably between 100 and 300 nm and most preferably between 200 and 300 nm.

15. Method according to any of claims 1 to 14, characterized in that the image recorded in the photoresist as surface relief hologram is transferred into the substrate material by an etching process.

16. Method according to any of claims 1 to 15, characterized in that the etching process is a plasma etching process.

17. Method according to any of claims 1 to 16, characterized in that the illumination beam (51) is scanned in a first direction across the holographic recording medium (79 ) and the mask (73), respectively , stepping the illumination (51) beam in a second direction perpendicular to the first direction, and then scanning the beam (51) again in the first direction and so on, such that the reference and object beams (75,74) travel simultaneously across the first face or the substrate (77) in optical contact with the first face;

18. Method according to any of the preceding claims 1 to 17 characterized in that the gap between the holographic recording layer and the mask is determined, e.g. interferometrically, and then the distance between the hologram and the recording medium adjusted to a predetermined value.

19. Method according to any of the preceding claims 1 to 18 characterized in that in the hologram reconstruction process the distance between the hologram and the substrate onto which the holographically recorded image is to be reconstructed is adjusted to the value as maintained between the holographic recording layer and the mask in the hologram formation process.

20. Method according to any of the preceding claims 1 to 19 characterized in that the reference beam is directed to a second face of the coupling element in a way that the

condition for total internal reflection at the interface between the recording medium and the ambient medium is fulfilled and so that the angle of incidence of the beam in the recording layer is less than 45°, preferably less than 42° and most preferably less than 40°.

21. Use of the method according to any of claims 1 to 19 for recording features of less than 1 μm, preferably less than 0.5 μm, contained in a mask in a hologram for use in microlithography.

22. Method of forming a hologram from a information containing mask, comprising the following steps:

- arranging a substrate bearing a layer of a holographic recording medium on a first face of a coupling element and in optical contact therewith;
- arranging a information containing mask in a spaced relationship and parallel to the substrate;
- generating an illumination light beam and then splitting the light beam into an object beam and a reference beam;
- directing the object beam through the mask to the substrate such that it overlaps with the reference beam in the holographic recording medium;

**further including the steps of**

- employing a photoresist as the holographic recording medium;
- directing the reference beam to a second face of the coupling element in a way that the condition for total internal reflection at the interface between the recording medium and the ambient medium is fulfilled and so that the angle of incidence of the beam in the recording layer is

less than 45°, preferably less than 42° and most preferably less than 40°;

- arranging the planes of polarisation of the object and reference beams incident on the holographic recording medium such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are also substantially orthogonal.

23. Method according to claim 22 characterized in that a photoresist is employed whose refractive index at the exposure wavelength is greater than 1.6 and preferably greater than 1.7.

24. Method according to claim 22 or 23 and any of claims 2 to 18.

25. Total internal reflection holographic recording apparatus for recording a hologram from a mask, comprising

- an optical coupling element for receiving a substrate on a first face;
- a substrate bearing a holographic recording medium, the substrate being in optical contact with said first face of the optical coupling element,
- at least one light source for generating a light beam;
- optical means for generating a collimated light beam of a selected cross-section;
- means, e.g. a beam-splitter, prism or the like, for generating two coherent light beams, a reference light beam and an object light beam;
- means for directing the reference light beam at a second

face of the coupling element such that it illuminates the interface between the first face and the ambient medium or the interface between a substrate in optical contact with said first face and the ambient medium at an angle greater than the critical angle;

- means for directing the object light beam at the first face of the coupling element such that it is aligned with the reference beam in the plane of the holographic recording medium on the substrate in contact with the first face;

characterized in that

- the holographic recording medium is a photoresist; and
- means are provided for arranging the planes of polarisation of the object and reference beams incident on the holographic recording medium such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are substantially orthogonal.

26. Apparatus according to claim 25 characterized in that the at least one light source is a laser light source emitting light of a wavelength below 300nm, and preferably of a wavelength between about 150 and 260 nm; and preferably between about 190 and 254 nm.

27. Apparatus according to claim 25 or 26, characterized in that the photoresist material is such that its thickness (d) and absorption (a) meet the condition $a * d < 1$.

28. Apparatus according to any of claims 25 to 27, characterized in that the photoresist material is such that that its contrast described by its gamma factor satisfies the condition $\gamma < 3$.

29. Apparatus according to any of claims 25 to 28, characterized in that a combination of polarisation angles of between 37 to 44°, preferably 39° for the reference beam and - 43 to -47°, preferably 45° for the object beam are applied.

30. Apparatus according to any of claims 25 to 29, characterized in that means are provided for adjusting the intensities of the object and reference beams such that the intensity of the object beam exceeds that of the reference beam.

31. Apparatus according to any of claims 25 to 30, characterized in that the intensity of the object beam exceeds that of the reference beam by at least of a factor 2 preferably by a factor of about 4.

32. Apparatus according to any of claims 25 to 31, characterized in that the thickness of the photoresist layer is less than 500 nm, preferably between 100 and 300 nm and most preferably between 200 and 300 nm.

33. Apparatus according to any of claims 25 to 32, characterized in that means are provided for scanning and stepping the incident light beam in a raster scan across the beam splitting means in a first and in a second direction, respectively, such that the reference and

object beams travel simultaneously across the first face or the substrate in optical contact with the first face;

34. Apparatus according to any of the preceding claims 25 to 33 further comprising

- means for measuring the gap between the hologram and a wafer being arranged in a spaced relationship to the hologram; and
- means for adjusting the parallelism and/or separation between the hologram and the wafer.

35. Apparatus according to any of the preceding claims 25 to 34 further characterized in that the directing means for the reference light beam further arranges that the angle of incidence of the reference beam in the holographic recording layer is less than 45°, preferably less than 42° and most preferably less than 40°.

36. Apparatus according to any of the preceding claims 25 to 35 characterized in that the photoresist employed has a refractive index at the exposure wavelength of greater than 1.6 and preferably greater than 1.7.

37. Total internal reflection holographic recording apparatus or system for recording a hologram from a mask, comprising

- an optical coupling element for receiving a substrate on a first face;
- a substrate bearing a holographic recording medium, the substrate being in optical contact with said first face of the optical coupling element,
- at least one light source for generating a light beam;

- optical means for generating a collimated light beam of a selected cross-section;
- means, e.g. a beam-splitter, prism or the like, for generating two coherent light beams, a reference light beam and an object light beam;
- means for directing the reference light beam at a second face of the coupling element such that it illuminates the interface between the first face and the ambient medium or the interface between a substrate in optical contact with said first face and the ambient medium at an angle greater than the critical angle;
- means for directing the object light beam at the first face of the coupling element such that it is aligned with the reference beam in the plane of the holographic recording medium on the substrate in contact with the first face;

**characterized in that**

- the holographic recording medium is a photoresist;
- means are provided for arranging the planes of polarisation of the object and reference beams incident on the holographic recording medium such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are substantially orthogonal; and
- in that the directing means for the reference light beam further arranges that the angle of incidence of the reference beam in the holographic recording layer is less than 45°, preferably less than 42°and most preferably less than 40°.

38. Apparatus according to claim 37 and any of claims 26 to 36.

39. Hologram recorded in a recording medium according to claims 1 to 20 or claims 22 to 24.

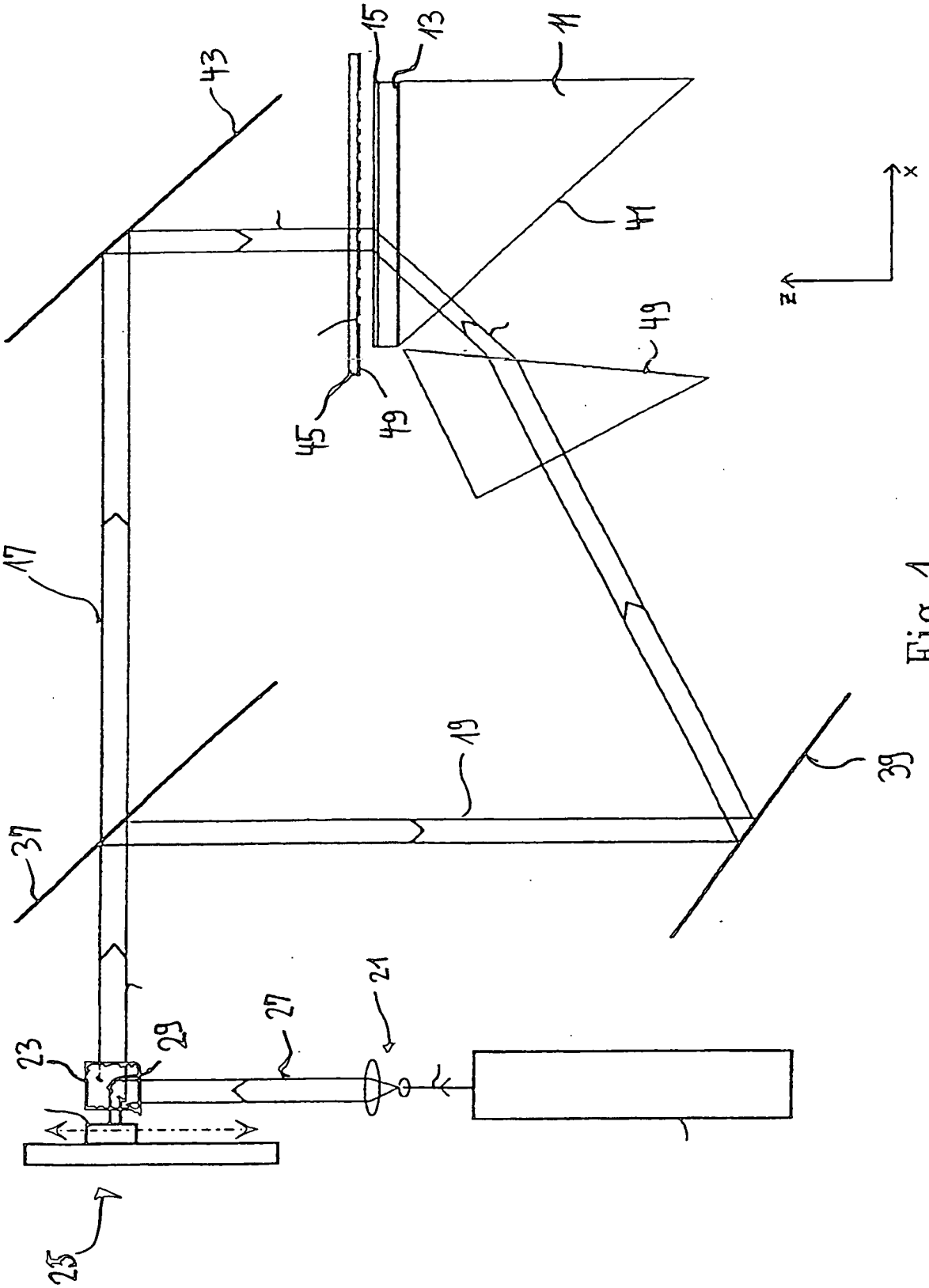
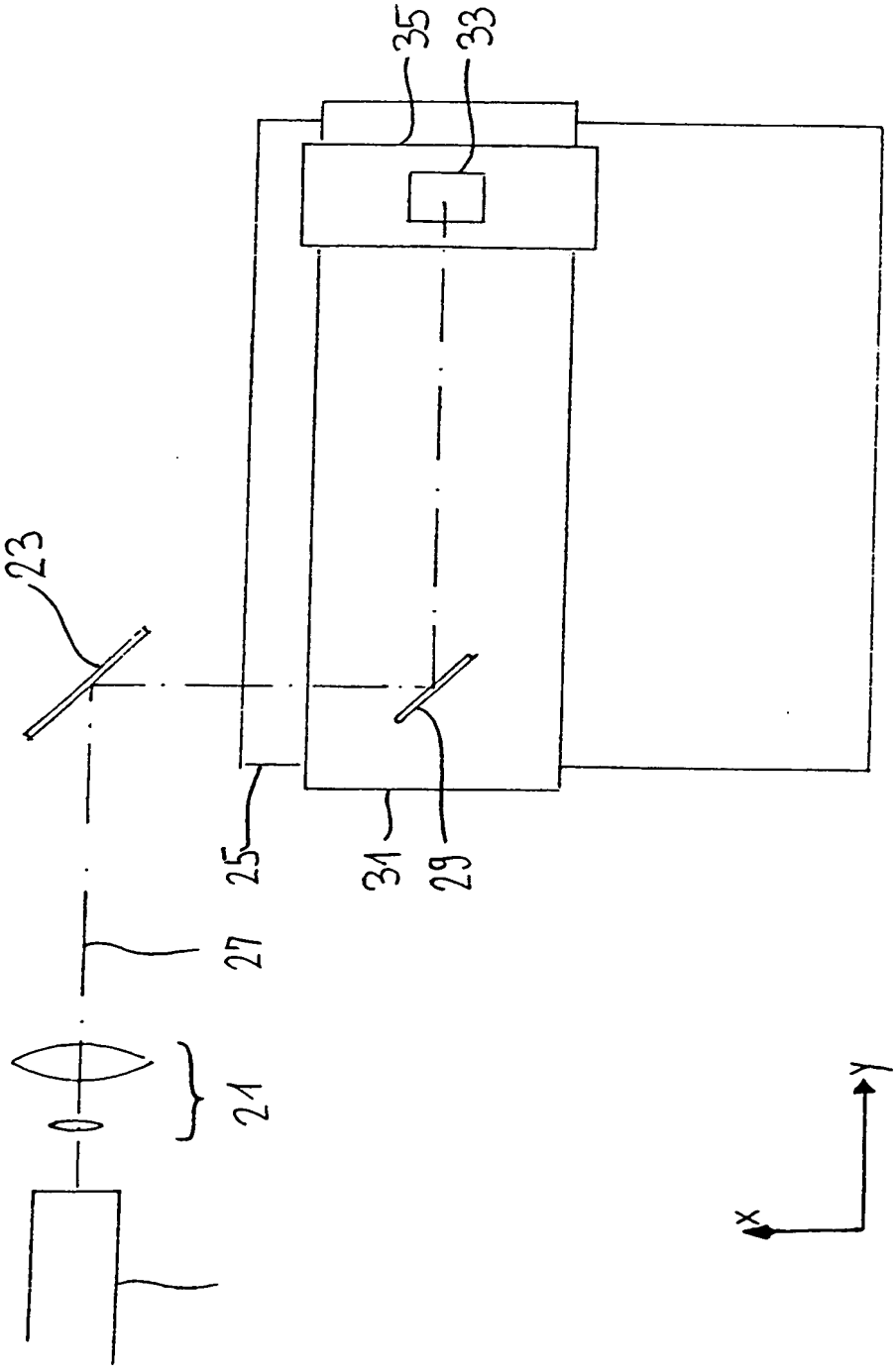



Fig. 1

Fig. 2



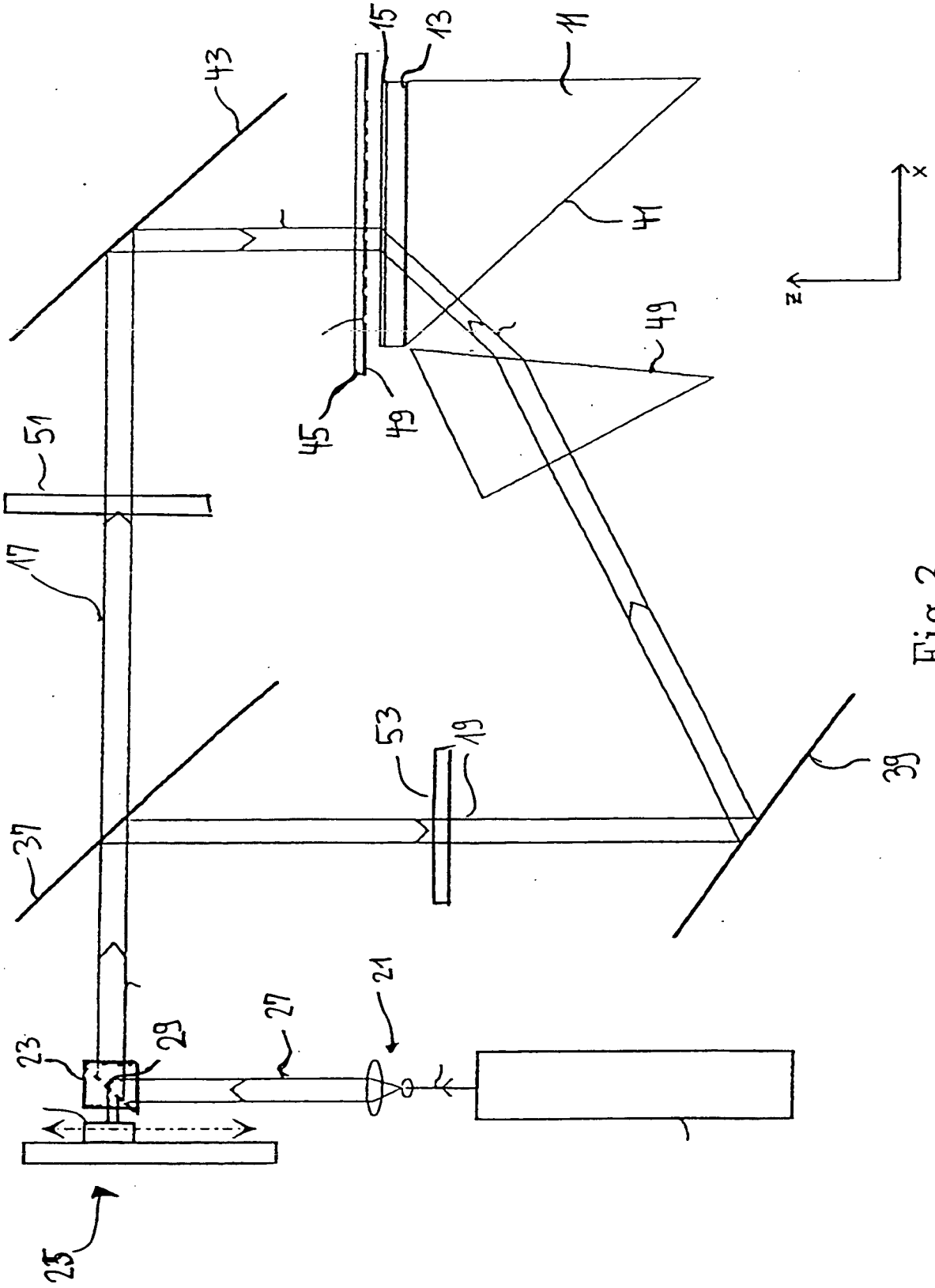



Fig.3

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 00/00794

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G03H1/00 G03F7/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G03H G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
WPI Data, PAJ, EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 5 640 257 A (CLUBE FRANCIS S M)<br>17 June 1997 (1997-06-17)<br>cited in the application<br>column 5, line 6 -column 6, line 57<br>figure 2<br>--- | 1,17,22,<br>25,33,37 |
| A | US 3 796 476 A (FROSCH A ET AL)<br>12 March 1974 (1974-03-12)<br>cited in the application<br>column 3, line 38 -column 4, line 51<br>figures 5,6<br>--- | 1,22,25,<br>37 |
| | -/-- | |

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 27 September 2000 | 05/10/2000 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Krametz, E |

Form PCT/ISA/210 (second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/IB 00/00794

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | GB 2 176 628 A (ROSS IAN NORMAN;DAVIS GILLIAN MARGARET)<br>31 December 1986 (1986-12-31)<br>page 1, line 6 - line 10<br>page 1, line 73 - line 86<br>page 2, line 47 - line 51<br>page 3, line 20 - line 35 | 1,8,21, 22,25, 26,37 |
| A | US 5 648 857 A (ANDO HIROSHI ET AL)<br>15 July 1997 (1997-07-15)<br>column 2, line 30 -column 4, line 10 | 1,22,25, 37 |

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter nal Application No
PCT/IB 00/00794

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 5640257 A | 17-06-1997 | GB 2271648 A | 20-04-1994 |
| | | DE 69327439 D | 03-02-2000 |
| | | DE 69327439 T | 10-08-2000 |
| | | EP 0593124 A | 20-04-1994 |
| | | JP 6308872 A | 04-11-1994 |
| US 3796476 A | 12-03-1974 | CA 974112 A | 09-09-1975 |
| | | DE 2140408 A | 01-03-1973 |
| | | FR 2148551 A | 23-03-1973 |
| | | GB 1344795 A | 23-01-1974 |
| | | JP 48028251 A | 14-04-1973 |
| | | JP 51039867 B | 30-10-1976 |
| GB 2176628 A | 31-12-1986 | EP 0257038 A | 02-03-1988 |
| | | WO 8607474 A | 18-12-1986 |
| | | JP 63500063 T | 07-01-1988 |
| US 5648857 A | 15-07-1997 | JP 7230243 A | 29-08-1995 |

# PATENT COOPERATION TREATY

# PCT



## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

| Applicant's or agent's file reference | FOR FURTHER ACTION | See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416) |
|---|---|---|
| 599-7452 | | |
| International application No. | International filing date *(day/month/year)* | Priority date *(day/month/year)* |
| PCT/IB00/00794 | 13/06/2000 | 11/06/1999 |
| International Patent Classification (IPC) or national classification and IPC<br>G03H1/00 | | |
| Applicant<br>HOLTRONIC TECHNOLOGIES PLC | | |

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 11 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

| Date of submission of the demand | Date of completion of this report |
|---|---|
| 09/01/2001 | 04.10.2001 |
| Name and mailing address of the international preliminary examining authority:<br>European Patent Office<br>D-80298 Munich<br>Tel. +49 89 2399 - 0 Tx: 523656 epmu d<br>Fax: +49 89 2399 - 4465 | Authorized officer<br>Noirard, P<br>Telephone No. +49 89 2399 2420 |

Form PCT/IPEA/409 (cover sheet) (January 1994)

# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/IB00/00794

## I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
**Description, pages:**

1-19 as originally filed

**Claims, No.:**

1-39 as originally filed

**Drawings, sheets:**

1/3-3/3 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

*(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

6. Additional observations, if necessary:

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

| | | | |
|---|---|---|---|
| Novelty (N) | Yes: | Claims | 5-19,26-34 |
| | No: | Claims | 1-4,20-25,35-39 |
| Inventive step (IS) | Yes: | Claims | |
| | No: | Claims | 5-19,26-34 |
| Industrial applicability (IA) | Yes: | Claims | 1-39 |
| | No: | Claims | |

2. Citations and explanations
**see separate sheet**

**VII. Certain defects in the international application**

The following defects in the form or contents of the international application have been noted:
**see separate sheet**

**VIII. Certain observations on the international application**

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
**see separate sheet**

**Re It m V**

**Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1.1 Reference is made to the following documents :

**D1**: US-A-3 796 476 (FROSCH A ET AL) 12 March 1974 (1974-03-12) cited in the application

**D2**: US-A-5 640 257 (CLUBE FRANCIS S M) 17 June 1997 (1997-06-17) cited in the application

**D3**: US-A-5 648 857 (ANDO HIROSHI ET AL) 15 July 1997 (1997-07-15)

Note: The references in brackets {..} relate to passages in the present application.

1.2 Negative statements : claims 1-4,20-25,35-39 lack novelty (Article 33(2) PCT), and claims 5-19,26-34 do not involve an inventive step (Article 33(3) PCT).

---

General comment concerning the novelty assessment with respect to document **D1.**
In the present description, the applicant acknowledges **D1** as pertinent prior art and argues how **D1** differs from the present application. However, it appears that :
* **D1** uses photoresists as holographic recording medium (see in **D1**, column 2, line 5), contrary to the statement page 1, lines 17-23 of the present application;
* **D1** teaches that the recording of transmission hologram (as disclosed Fig. 6 and column 4, lines 1-34) is "of greater advantage" (with respect to reflection hologram) (cf. column 4 lines 31-34), contrary to the statement page 5, lines 19-21 of the present application;
* **D1** does not teach to use an angle of incidence of 45° for the reference beam within the recording layer, but states that "it is important that the reflexion takes place exactly under the critical angle of total reflexion" (see column 3, lines 59-61) which angle is not necessary 45° (especially with photoresist as recording material). Instead, D1 uses 45° as polarisation angle (see abstract) and as reproduction angle (cf. column 3, line 15).

Furthermore, the applicant finds incorrect **D1**'s statement that "the plane of polarisation is rotated by 90° on TIR" {see page 5, lines 1-14}, however, page 11, lines 6-7 of the present application, the applicant mentions a polarisation rotation at the critical angle. If that statement is incorrect, it is not clear enough from the present description how, according to the last item of claim 1, the planes of polarisation of the beams can be made

perpendicular. The two polarisation plates used {ref. 51 and 53, Fig. 3} appear not *prima facie* to be able to fulfill this perpendicularity condition (lack of disclosure, Article 5, PCT). It should be noticed that the set up disclosed in **D3** seems to fulfill the perpendicularity condition but can absolutely not be derived from the present description.

Therefore, in establishing this opinion, the statements related to **D1** in the description have been disregarded, and it has been assumed that, irrespective of D1's theoretical explanations, **the method and system for making TIR hologram disclosed in D1 is fully relevant according to the present set of claims.**

2. As far as independent claims 1, 22, 25, and 37 and dependent claims 2-4, 20, 21, 23-25, 35, 36, and 38-39 can be understood (see item VIII, below), their subject matter lacks novelty (Article 33(2) PCT) having regard to the teaching of document **D1** for the following reasons :-

2.2 Document **D1** discloses a method of forming a hologram from a information containing mask (see abstract and Fig. 6), comprising the following steps:
- arranging a substrate (5) bearing a layer of a holographic recording medium (4, H2) on a first face of a coupling element (7) and in optical contact therewith;
- arranging a information containing mask (2) in a spaced relationship and parallel to the substrate (5);
- generating an illumination light beam and then splitting the light beam into an object beam (O) and a reference beam (B1) (implicit from the "conventional manner used", see column 2, line 53);
- directing the reference beam (B1) to a second face of the coupling element (7) in a way that the condition for total internal reflection at the interface between the recording medium and the ambient medium is fulfilled (see Fig. 6 and column 3, lines 59-61);
- directing the object beam (O) through the mask (2) to the substrate (5) such that it overlaps with the reference beam in the holographic recording medium (4) (cf Fig. 6);
- employing a photoresist as the holographic recording medium (4) (cf. column 2, line 5); and,
- arranging the planes of polarisation of the object (O) and reference (B1) beams incident on the holographic recording medium such that their polarisation vectors are

substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident (B1) and totally internally reflected (B2) reference beams are also substantially orthogonal (see Fig. 6 and column 4, lines 1-34).
Therefore, **claim 1** lacks novelty.

2.3 Furthermore, **D1** also discloses :-
* that only the transmission hologram is recorded (cf. Fig. 6) {**claim 2**};
* that the refractive index of the recording medium is greater than 1.6, (this applies for photoresist) {**claim 3**};
* that the plane of polarisation of the object beam is at 45° to the plane of incidence of the reference beam at the holographic recording layer (cf. col. 3. lines 48-53 and col. 4, lines 12-16) {**claim 4**};
* that the reference beam (B1) is directed to a second face of the coupling element in a way that the condition for total internal reflection at the interface between the recording medium and the ambient medium is fulfilled (column 3, lines 59-61) and also that the angle of incidence of the beam in the recording layer is less than 45° (which applies for the photoresist disclosed in D1) {**claim 20**};
* the use of the method of claim 1 for recording features less than 1 micron (cf. col. 1, lines 46-50) {**claim 21**}.

Due to the lack of conciseness of the claims (see item VIII), D1's disclosure also anticipates **claims 22-24**.

2.4 Document **D1** discloses a Total Internal Reflection holographic recording apparatus (cf. Fig. 6, and column 4, lines 1-34) for recording a hologram from a mask (2), comprising
1/- an optical coupling element (7) for receiving a substrate (5) on a first face;
2/- a substrate (5) bearing a holographic recording medium (4), the substrate being in optical contact with said first face of the optical coupling element (7);
3/- at least one light source for generating a light beam;
4/- optical means for generating a collimated light beam of a selected cross-section;
5/- means, e. g. a beam-splitter, prism or the like, for generating two coherent light beams, a reference light beam (B1) and an object light beam (O);
6/- means for directing the reference light beam at a second face of the coupling

element (7) such that it illuminates the interface between a substrate (5) in optical contact with said first face and the ambient medium at an angle greater than the critical angle (column 3, lines 42-47);
7/- means for directing the object light beam (O) at the first face of the coupling element such that it overlaps with the reference beam (B1) in the plane of the holographic recording medium (4) on the substrate (5) in contact with the first face;
8/- a photoresist as holographic recording medium (see column 2, line 5);
9/- means for arranging the planes of polarisation of the object (O) and reference (B1) beams incident on the holographic recording medium such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident (B1) and totally internally reflected (B2) reference beams are substantially orthogonal (see Fig. 6 and column 4, lines 1-34).
Although explicitly not present in D1, the previous features number 3/,4/,5/,7/ are implicitly disclosed from the conventional manner of making hologram stated in D1 (see column 2, lines 52-55)
therefore, **claim 25** is not new.

The added features of **claims 35 and 36** have already been identified in D1 (see §2.3, above) hence these claims are not novel, too.

Due to the lack of conciseness of the claims (see item VIII), D1's disclosure also anticipates **claims 37 and 38**.

Any hologram issued from the method taught in D1 for recording transmission hologram (cf. Fig. 6) deprives **claim 39** of novelty.

3. As far as they are understood (see section VIII below), dependent claims 5-9, 11-19, 26-28, and 30-34 cannot be considered as involving an inventive step (Article 33(3) PCT) for the reasons hereafter developed:

Hereafter, document **D1** will be considered as closest prior art, which features in common with the claims have already been listed in §2.1 to §2.4 above.

3.1 Document **D2** teaches also a method and an apparatus for forming a TIR hologram. Particularly, D2 discloses and teaches :
* to use a XY scanner (21) for scanning the object beam across the mask (cf. in D2 column 5, lines 30-55) {**claims 17, 33**}; and,
* to use means for adjusting the intensities of the object and reference beams (29, 29') {**claim 30**}.
It is therefore considered that combining the features disclosed in **D1** and in **D2** comes within the scope of the customary practice followed by the person skilled in the art of TIR holography as employed in microlithography.

3.2 Following the clarity objections raised against the subject matter of **claims 5, 9, 27**, (see item VIII, below), it is at present not possible to extract relevant additional features from the present wording of these claims. They are thus considered not to be inventive.

3.3 The additional features of **claims 6-8, 11-16,18-19,26,28,31,32,34**, relate to known features and selections in the field of TIR holography as employed in microlithography (cf. the thickness, contrast, and sensibility of the recording medium, the intensity ratio between the object and reference beams of the deep UV laser, the etching and transfer process and the fine positioning process). Hence, these features cannot involve an inventive step for their respective claim.

3.4 As to the subject matter of **claims 10 and 29**, the close relationship it has with **D1**'s teaching does not permit to establish an inventive step (the polarisation angles claimed are too close for establishing a clear difference).

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4. The industrial applicability (Article 33(4) PCT) is clearly present for the subject matter of all the claims.

**Re Item VII**

**Certain defects in the international application**

5.1 Except for claim 17, the features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

5.2 Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in document D3 is not mentioned in the description.

5.3 The description in not clear in the following respect :-
* in Figs 1&3, the mask pattern is referenced 47 instead of 49 (cf. page 16, line 7);
* page 18, line 12, the reference number 55 is not present in the drawings.

5.4 In the description, on page 1, lines 14-15, it is stated that the content of another document is "incorporated by reference". As it is clear from the Guidelines (see GLII-4.1(i)), such passages relating to the disclosure of the invention should be avoided.

**Re Item VIII**

**Certain observations on the international application**

Certain claims do not meet the requirement of Article 6 PCT in that the subject matter for which protection is sought lacks clarity, conciseness or is not fully supported by the description for the following reasons:-

6.1 It appears that the subject matter of independent **claims 22 and 37** is respectively identical to that of dependent claim 20 {when made dependent on claim 1} and dependent claim 35 {when made dependent on claim 25}, therefore the aforementioned claims 22 and 37 lack conciseness.
This lack of conciseness objection holds also for the subject matter of **claims 23** {similar to claims 1&2&20}, **24** {similar to claims 1&20& 2-18}, and **38** {similar to claims 25&35&26-36}.

6.2 The present wording of **claim 2** is more an attempt to define the subject matter in terms of result to be achieved than a clear statement of a method step. Thus, the matter for which protection is sought is not clearly defined for this claim.

6.3 The subject matter of **claims 5 and 27** is unclear because no unities are specified for the components {a and d} of the stated formulae {in the description "a" is in micron page 2, lines 31 and in nm page 6, line 14}.

6.4 From present wording of **claim 9**, it is not possible to derive any clear step for the method. Moreover, the stated "polarisation angles" should have been defined.

6.5 in **claims 10, 29** it is not clear how the polarisation angles can be 39° and 45° (which sum is not 90°) although the polarisations of the reference and object beams are orthogonal {see respective appended independent claims}.

6.6 In **claim 16**, "the etching process" lacks an antecedent basis when this claim is made dependent on claims 1-14.

6.7 In **claim 17**, "the illumination beam" lacks an antecedent basis, furthermore, the reference numbers appear not to correspond to the elements shown in the accompanying Figures. In the last but one line of the claim, it has been assumed that the beams travel across the "first face of the substrate". This last objection holds also for the subject matter of **claim 33**.

6.8 In **claim 18**, it has been assumed that the distance between the mask and the recording medium is adjusted.

6.9 **Claim 19** is of obscure scope because the added step appears not to be related to the method of forming a hologram claimed.

6.10 In **claim 20**, the word "so" in "...and so that the angle of incidence of the beam..." seems to lead to the conclusion that the second condition (i.e. that the angle is less than 45°) is a consequence of the first one (i.e. that TIR is achieved). However, the description makes it clear that the two conditions should be independently fulfilled : the TIR should be fulfilled (e.g. the angle is greater than 33.7° for n=1.8) and also the

angle should be less than 45°.
This objection holds also for the subject matter of **claim 22**.

6.11 In **claims 25 and 37**, the "means for directing the reference light" is stated such that the reference light "illuminates the interface between the first face and the ambient medium [or...] at an angle greater than the critical angle". This layout, involving that a layer of ambient medium splits the means for directing the reference light and the substrate, is not supported by the description and is unclear because, in that case, no reference beam would arrive to the recording layer (due to TIR).
Furthermore, the term "aligned" (cf. page 26, line 7) is somehow misleading. The term "overlapped" would have been more appropriate.

6.12 In **claim 29**, it is not clear to which polarisation angles the claim is referring.

6.13 Claim 34 is of obscure scope because the added features appear not to be linked to the TIR holographic recording apparatus claimed.

PATENT COOPERATION TREATY

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# PCT

## NOTIFICATION OF ELECTION

(PCT Rule 61.2)

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| **Applicant**<br>HAN, Woo-Sung et al | |

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

09 January 2001 (09.01.01)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

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